

5.16.14 MARSHALL TESTS OF BITUMINOUS MIXES
(Kansas Test Method KT-14)

a. SCOPE

This method of test covers the procedures for testing bituminous mixes to determine:

a.1. Optimum Asphalt Content.

a.2. Density Characteristics, including voids content.

a.3. Stability Characteristics, including resistance to plastic flow and flow properties.

a.4. This method is limited to mixes containing asphalt cement and containing aggregate having a maximum size of 25 mm (1 in). KT-14 reflects testing procedures found in AASHTO T 245 and T 269.

b. REFERENCED DOCUMENTS

b.1. KT-15; Bulk Specific Gravity and Unit Weight of Compacted Bituminous Mixtures

b.2. KT-57; Determination of Asphalt Content and Gradation of Hot Mix Asphalt Concrete by the Ignition Method

b.3. KT-58; Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

b.4. AASHTO M 231; Balances Used in Testing of Materials

b.5. AASHTO T 245; Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus

b.6. AASHTO T 269; Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures

b.7. ASTM D 1559; Test Method for Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus

c. APPARATUS

c.1. Specimen Mold Assembly: A cylindrical mold having an inside diameter of 101.6 ± 0.25 mm (4.000 ± 0.010 in)¹ and a length of approximately 90 mm (3 7/16 in). The mold is open at each end and is equipped with a removable collar and a base plate about 15 mm (9/16 in) in thickness. A minimum of three molds is recommended.

c.2. Compaction Hammer: The compaction hammer consists of a hammer having a flat circular tamping face, 98.4 mm (3 7/8 in) in diameter, and appropriate extension rod with handle which acts as guide for a free falling weight. The weight shall weigh $4,536 \pm 18$ g (10 ± 0.04 lb) and have a free fall of 457.2 ± 2.5 mm (18 ± 0.1 in). The hammer may be operated manually or be driven with a motor. Two compaction hammers are recommended.

c.3. Compaction Pedestal: The compaction pedestal is a wood block approximately 300 by 300 by 450 mm (12 by 12 by 18 in). A 300 by 300 by 25 mm (12 by 12 by 1 in) steel plate is securely fastened to the top of the block. The pedestal is set on and securely fastened to a solid concrete slab with the vertical axis plumb and the top level.

c.4. Specimen Mold Holder: The specimen mold holder has a semi-circular base and a flanged top to hold the specimen mold in place during the compaction process. Any equivalent hold down device which performs the same function is satisfactory.

c.5. Specimen Extruder: An extruder for the removal of the specimens from the mold is recommended. The unit may consist of a steel frame to hold the mold, a hydraulic jack and a steel disc approximately 13 mm (1/2 in) thick and 100 mm (3.9 in) in diameter.

c.6. Testing Assembly: This includes a breaking head, a load measuring device and two flow meters, dial micrometers or an automatic stability/flow recording device. The testing assembly shall be calibrated at intervals not exceeding two years.

c.6.a. Breaking Head: The breaking head consists of two accurately machined cylindrical segments having an inside radius of 50 mm (2 in). The lower segment is mounted on a base having two perpendicular guide rods or posts extending upward. Sleeves in the upper segment are positioned to guide the two segments together without appreciable binding or loose motion on the guide rods.

¹ AASHTO T 245 requires the compaction molds to be 101.6 ± 0.13 mm (4.000 ± 0.005 in).

c.6.b. Flow Meters: Two flow meters graduated in 0.25 mm (.01 in) increments and conforming to the details set forth in ASTM D 1559 or two micrometer dials graduated in 0.025 mm (0.001 in) increments are used to measure plastic flow. Instead of the flowmeter, a micrometer dial or stress-strain recorder graduated in 0.25 mm (0.01 in) divisions.

c.6.c. Loading Device: The loading device may be either a screw jack or a hydraulic system, manually or motor operated to produce a constant vertical movement of 50 ± 2 mm/min (2 ± 0.1 in/min) during application of load.

c.6.d. Load Measuring Device:

c.6.d.1. Proving ring assembly consisting of a 20 kN (5,000 lb) capacity proving ring, sensitive to 44.5 N (10 lb) up to 4.45 kN (1,000 lb) and to 111.2 N (25 lb) above 4.45 kN (1,000 lb). The proving ring is equipped with a micrometer dial graduated in 0.0025 mm (0.0001 in) increments.

The upper portion of the ring is attached to the testing frame and the lower portion transmits the load to the breaking head.

c.6.d.2. In lieu of the proving ring assembly, any suitable load measuring device may be used providing the capacity and sensitivity meet the above requirements.

c.7. Heating Equipment: Ovens or hot plates for heating aggregates, bituminous material, specimen molds, compaction hammers and other associated items required for mixing and molding. It is recommended that, when possible all heating units be thermostatically controlled to maintain the required temperature within $\pm 2.8^{\circ}\text{C}$ ($\pm 5^{\circ}\text{F}$). Suitable shields, thick steel plates or pans of sand shall be used on the surfaces of hot plates to minimize localized overheating.

c.8. Mixing Apparatus: Mechanical mixing is recommended. Any type of mechanical mixer may be used provided it will produce a well coated, homogeneous mixture of the required amount in the allowable time and further that the mixing paddle or whip does not fracture or pulverize aggregate fractions during the mixing process. The bowl employed with the mixer shall be of such a nature that essentially all of the batch can be removed. More than one mixing bowl is recommended unless the mixer is equipped with a heating jacket to keep the bowl heated during the mixing process.

c.9. Water Bath: The water bath shall be approximately 140 mm (5 1/2 in) deep and shall be thermostatically controlled so as to

maintain the bath at $60 \pm 1^{\circ}\text{C}$ ($140 \pm 2^{\circ}\text{F}$). The tank shall have a perforated false bottom or be equipped with a shelf for adequately supporting specimens approximately 50 mm (2 in) above the bottom of the bath.

c.10. Miscellaneous Equipment:

c.10.a. Containers for heating aggregates, flat-bottom metal pans or other suitable containers.

c.10.b. Containers for heating bituminous material, beakers, ointment cans, pouring pots, etc. may be used.

c.10.c. Mixing tool, steel towel or spatula, for spading and hand mixing.

c.10.d. Thermometers for determining temperatures of aggregate, bitumen and bituminous mixtures. Armored glass or dial type with metal stem thermometers may be used. A range of at least 10 to 200°C (50 to 400°F) with a sensitivity of 2.8°C (5°F) is required.

c.10.e. Thermometer for water bath sensitivity to 0.1°C (0.2°F).

c.10.f. The balance shall conform to the requirements of AASHTO M 231 for the class of general purpose balance required for the principal sample mass of the sample being tested.

c.10.g. Large Spoon, for cleaning of mixing bowl or placing mixture in mold cylinders.

c.10.h. Specimen height measuring device.

c.10.i. Gloves for handling hot equipment.

c.10.j. 100 mm (4 in) dia. paper discs.

d. DETERMINATION OF MIXING AND COMPACTING TEMPERATURE

d.1. The temperatures to which the asphalt cement must be heated to produce a viscosity of 170 ± 20 cSt (85 ± 10 SFS) shall be the mixing temperature.

d.2. The temperature to which the asphalt cement must be heated to produce a viscosity of 280 ± 30 cSt (135 ± 15 SFS) shall be the compacting temperature.

e. SAMPLE PREPARATION

e.1. Hot Plant Mixes with Asphalt: Mix the sample of mixed material thoroughly and split out not less than three increments weighing approximately 1,200 g for a 100 mm (4 in) diameter plug. Bring the increments to within the limits of the compacting temperature determined in **d.2.** prior to compacting. See KT-57 **d.** for method of quartering to obtain proper sized sample.

e.2. Laboratory Prepared Mixes: *If using hydrated lime as an antistripping agent, then refer to the attached Addendum.*

e.2.a. Number of Specimens: It is recommended that each aggregate combination be tested at six different asphalt contents, in 1/2 percent increments. At least three specimens are prepared for each percentage of asphalt. Prepare one extra aggregate and asphalt sample to be mixed first and then thrown away. This sample is to "butter" the mixing bowl and paddle and thus reduce material loss when mixing the test specimens.

e.2.b. Preparation of Virgin Aggregates: Dry individual aggregates to constant mass at 105 to 110°C (221 to 230°F). Separate the individual aggregates by dry screening into desired fractions. The following size fractions² are recommended as a minimum:

25.0 to 19.0 mm (1 to 3/4 in)	4.75 to 2.36 mm (No.4 to No.8)
19.0 to 12.5 mm (3/4 to 1/2 in)	2.36 to 1.18 mm (No.8 to No.16)
12.5 to 9.5 mm (1/2 to 3/8 in)	Passing 1.18 mm (Passing No.16)
9.5 to 4.75 mm (3/8 in to No.4)	

e.2.c. Preparation of Reclaimed Material: Place the reclaimed material in a 50 to 80°C (125 to 175°F) draft oven for 1 1/2 to 2 hours, to soften. Transfer the materials to the mixing bowl and mix for two minutes in order to breakdown the reclaimed material to the recommended sizes. (Mixer will mix approximately 3,500 g.) Other methods of breakdown are acceptable provided they do not fracture aggregates or lose an excessive amount of material in the process. Separate the reclaimed material into desired fractions by screening, when cool enough to screen. The following size fractions are recommended:

19.0 to 12.5 mm (3/4 to 1/2 in)	4.75 to 2.36 mm (No.4 to No.8)
12.5 to 9.5 mm (1/2 to 3/8 in)	Passing 2.36 mm (Passing No.8)
9.5 to 4.75 mm (3/8 in to No.4)	

Weigh each fraction and record percentage of total sample.

² AASHTO T 245 **3.2** fraction recommendations use fewer sieve sizes.

e.2.d. Preparation of Mixes: Combine the individual aggregates or reclaimed material and virgin aggregates by weighing out in a separate pan for each test specimen, proportionate amounts of each size fraction for each individual aggregate to produce the desired combined aggregate with a batch mass of approximately 1,125 g. This should be sufficient to produce a compacted specimen 64 ± 3 mm ($2.5 \pm 1/8$ in) thick³. Adjust the mass of the batch as needed to produce compacted specimens of 64 ± 3 mm ($2.5 \pm 1/8$ in) thickness.

Heat the aggregate and asphalt within the limits of mixing temperature determined in **d.1**. Charge the mixing bowl with the heated aggregate and form a crater in the top. Add the required amount of asphalt and mix the aggregate and asphalt until thoroughly coated, at least 2 minutes. Care should be taken to keep all of the sample in the mixing bowl during this process.

Place the mix in a 135°C (275°F) oven and age⁴ the material for 2 hours as outlined in KT-58 **g.5**. At the end of the aging time place the mix in an oven set at the compaction temperature or reset the 135°C (275°F) oven temperature to reflect the compaction temperature. Allow the mix to adjust to the new temperature prior to removing for compaction.

e.2.e. Compaction of Specimens: Prior to the addition of the asphalt to the batches, thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat the mold assembly and hammer in boiling water, in an oven or on a hot plate, to a temperature between 90 and 175°C (200 and 350°F). Assemble the mold, base plate and collar and place a paper disc cut to size in the bottom of the mold.

Place the entire hot batch of aggregate-asphalt mixture in the mold, spade vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior of the mold. Smooth the surface of the mix to a slightly rounded shape⁵. The temperature of the mix just prior to compaction shall be within the limits determined in **d.2**. Place a paper disc on top of the mix.

Place the mold assembly, including the collar, on the pedestal, fasten securely with the mold holder and apply 50 or 75 blows^a with the compaction hammer. Each blow must have the

³ AASHTO T 245 **3.4.2** requires compaction height to be 63.5 ± 1.27 mm (2.5 ± 0.05 in).

⁴ The aging process reflects information found in the proposed AASHTO PP2, Short and Long Term Aging of Bituminous Mixes.

⁵ AASHTO T 245 **3.5.1** requires the removal of the collar, then smoothing the surface of the mix. With the aggregates used by KDOT the material may overflow the mold.

prescribed free fall of 457 mm (18 in) with the axis of the compaction hammer held perpendicular to the base of the mold assembly during the compaction process. Remove the base plate and collar, and reverse and reassemble the mold. Apply the specified number of blows to the reversed specimen. After compaction, remove the mold assembly from the pedestal. Place the mold into the extractor and pop the plug loose from the mold. Permit the plug to cool in this state until the next plug has been processed. Extrude the initial plug out of the mold and pop the next plug loose. Carefully transfer the extruded plug to a smooth, flat surface and allow it to stand until the plug reaches room temperature⁶.

Note **a**: Traffic volume in the Design Lane determines the number of blows. **(See subsection 5.18.02 a.5.a. for traffic volume criteria.)**

e.2.f. Thickness of Specimen: Measure the specimen thickness to the nearest 0.025 mm (0.001 in). If the specimen thickness is less than 60 mm (2.375 in) or more than 67 mm (2.625 in), discard it and mold a replacement having a thickness within these limits.

e.2.g. Determination of Specific Gravity and Unit Weight: Determine the specific gravity and unit weight by the appropriate method as outlined in KT-15.

e.2.h. After determining the specific gravity for all of the specimens, proceed to **f**.

f. TEST PROCEDURE

Immerse the specimens in a $60 \pm 1^{\circ}\text{C}$ ($140 \pm 2^{\circ}\text{F}$) water bath for 30 to 40 minutes⁷. Thoroughly clean the guide rods and inside surfaces of the test heads prior to making the test. Lubricate the guide rods so that the upper test head slides freely over them. Remove the specimen from the water bath and place in the breaking head. The elapsed time for the test from removal of the test specimen from the water bath to the maximum load determination shall not exceed 30 sec. Place the complete breaking head assembly in position on the testing machine. Place the flow meters, where used, in position over the guide rods and adjust the flow meters to zero. Hold the flow meters firmly against the upper segment of the breaking head while the test load

⁶ AASHTO T 245 3.5.2 requires the plug to stand overnight at room temperature.

⁷ AASHTO T 245 4.1 also permits placing the plug in an oven for 2 hours.

is being applied. Avoid using excess pressure against the testing head while determining flow.

Apply the load to the specimen by a constant rate of movement of the load jack or testing machine head of 50 mm (2 in) per minute until a maximum load is reached and the load decreases as indicated by the proving ring dial. Record the maximum load noted on the testing machine or converted from the proving ring micrometer dial reading.

Release the flow meter sleeves or note the micrometer dial readings, where used, the instant the maximum load begins to decrease. Note and record the indicated flow values or equivalent units in 0.25 mm (0.01 in) if micrometer dials are used to measure flow.

For specimens other than 62.9 - 64.1 mm (2.476 - 2.525 in) in thickness, adjust the load using the proper correction factor from Table 5.16.14-1.

Table 5.16.14-1 Stability Correction Ratio

Thickness of Specimen in mm (in)	Correction Ratio
60.3 - 61.2 (2.375 - 2.410)	1.07
61.3 - 62.9 (2.411 - 2.475)	1.04
63.0 - 64.1 (2.476 - 2.525)	1.00
64.2 - 65.3 (2.526 - 2.570)	0.97
65.4 - 66.7 (2.571 - 2.625)	0.94

NOTE: The measured stability of a specimen multiplied by the ratio for the thickness of the specimen equals the corrected stability for a 63.5 mm (2 1/2 in) specimen.

g. EVALUATION OF SPECIFIC GRAVITY AND STABILITY DATA:

g.1. Specific Gravity of Molded Specimens:

g.1.a. If the difference between the specific gravity of a single specimen in a set of three specimens and the average of the set is greater than 0.025, discard the entire set and mold a new set.

g.1.b. If the difference between the specific gravity of a single specimen in a set of three specimens and the average of the set is greater than 0.014 and not greater than 0.025, discard the results of the single specimen and use the results of the tests on the remaining two specimens to compute the average specific gravity of the set.

g.1.c. If the difference between the specific gravity of a single specimen in a set of three specimens and the average specific gravity of the set in question is not greater than 0.014, the specific gravity of the specimen is acceptable and may be used to determine the average specific gravity.

g.2. Stability of Molded Specimens:

If the difference between the stability of a specimen and the average stability of the set of three specimens is not greater than the CV₁ values shown in Table 5.16.14-2 the specimen is acceptable for use in determining the average stability of the set.

If this difference is greater the CV₁ value but not greater than the CV₂ values, the specimen will be eliminated in the calculation of the average stability. Not less than two specimens will be used when determining the set average stability.

If the difference between the stability of any specimen of a set and the average stability of the set is greater than CV₂ values shown in Table 5.16.14-2, the entire set will be discarded and another set obtained.

Table 5.16.14-2 Stability Evaluation

Stability Range in N (lbf) (Based on Mean of Set)			CV ₁	CV ₂
0 - 2224	(0 - 500)	.....	160 (35)	.....310 (70)
2228 - 4448	(501 - 1000)	.....	290 (65)	.....580 (130)
4452 - 6672	(1001 - 1500)	.....	440 (100)	.....890 (200)
6676 - 8896	(1501 - 2000)	.....	580 (130)	.....1160 (260)
8900 - 11120	(2001 - 2500)	.....	730 (165)	.....1470 (330)
11124 - 13344	(2501 - 3000)	.....	870 (195)	.....1730 (390)
13348 - 15568	(3001 - 3500)	.....	1000 (225)	.....2000 (450)
15572 - 17792	(3501 - 4000)	.....	1160 (260)	.....2310 (520)
17796 - 20016	(4001 - 4500)	.....	1290 (290)	.....2580 (580)
20020 - 22240	(4501 - 5000)	.....	1420 (320)	.....2850 (640)

h. REPORT (See section 5.17.04 for methods of calculation)

The report includes the following information for each combination of aggregates and each asphalt content:

- h.1.** Average density, kg/m^3 (lb/ft^3) for each set of specimens.
- h.2.** Average maximum stability in N (lbf), corrected when required, for each set of specimens.
- h.3.** Average flow value, in 0.25 mm (hundredths of an inch), for each set of specimens.
- h.4.** Average mixing temperature, $^{\circ}\text{C}$ ($^{\circ}\text{F}$), for each set of specimens.
- h.5.** Average compacting temperature, $^{\circ}\text{C}$ ($^{\circ}\text{F}$), for each set of specimens.
- h.6.** Stability and flow test temperature, $^{\circ}\text{C}$ ($^{\circ}\text{F}$).
- h.7.** Average % voids, total mix, for each set of specimens, (Pa) (See Section 5.17.04).
- h.8.** Average % of total voids filled with asphalt for each set of specimens (VFA).
- h.9.** Average % of voids in aggregate only (VMA).
- h.10.** Maximum percentage of asphalt allowed for high temperature protection (P'b).
- h.11.** Recommended asphalt percentage for initial plant operation.
- h.12.** Bearing Capacity.
- h.13.** Theoretical Maximum Specific Gravity.

Show values for **h.1.**, **h.2.**, **h.7.**, **h.8.**, **h.9.**, **h.12.**, and **h.13.** using KDOT Form 701.

**ADDENDUM TO KT-14
FOR INCLUDING LIME AS AN ANTISTRIPPING AGENT**

The following information provides KT-14 with steps to incorporate hydrated lime as an antistripping agent.

Delete e.2.d. and replace with the following:

e.2.d. Preparation of Mixes: Combine the virgin aggregates by weighing in a separate pan for each test specimen, proportionate amounts of each size fraction for each individual aggregate to produce the desired combined aggregate with a batch mass of approximately 1,125 g. Include the hydrated lime mass required to meet the specified percent of lime for the project as part of the total batch mass. The total aggregate mass should include lime, virgin aggregate, and reclaimed material (if applicable). This should be sufficient to produce a compacted specimen 64 ± 3 mm ($2.5 \pm 1/8$ in) thick. Adjust the mass of the batch as needed to produce compacted specimens of 64 ± 3 mm ($2.5 \pm 1/8$ in) thickness.

e.2.d.1. Determine the SSD for the combined aggregate gradation. Add three percent of moisture to the percent moisture required to reach the SSD condition of the combined aggregate.

e.2.d.2. Place the combined virgin aggregate and hydrated lime in a mixing bowl. Carefully mix until the hydrated lime is combined with the aggregate. Add the appropriate water content, as determined in **e.2.d.1.**, and thoroughly mix.

e.2.d.3. Oven dry the aggregate mix at approximately 110°C (230°F) to a constant mass.

e.2.d.4. Combine the virgin aggregate material with the reclaimed material, if applicable, and thoroughly mix. Heat the combined aggregate and asphalt within limits of the mixing temperature determined in **d.1.** Charge the mixing bowl with the heated aggregate and form a crater in the top. Add the required amount of asphalt and mix the aggregate and asphalt until thoroughly coated, at least 2 minutes. Care should be taken to keep all of the sample in the mixing bowl during this process.